A Toolkit for Resource Equivalency Analysis for Environmental Damage in the European Union

REMEDE

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Outline

- Overview of resource equivalency analysis
- Overview of the draft toolkit
  - Initial evaluation
  - Determining the debit
  - Determining the credit
  - Scaling remediation
  - Remediation planning, implementation, monitoring and reporting
- A brief example

What is “Resource Equivalency Analysis”?

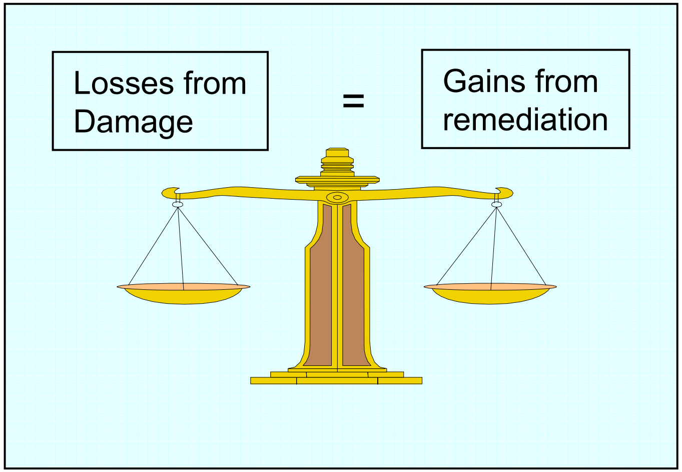
- Resource Equivalency Analysis (REA), or the related method of Habitat Equivalency Analysis (HEA) as a method used to calculate environmental damage and liability
  - Identified in ELD as preferred approach
  - Based on methods developed in USA
  - Quantifies environmental liabilities based on the amount of remediation that is needed to compensate for some environmental damage

Resource Equivalency Analysis: General Principles

- Compensation for damaged environmental resources or lost “services” can be provided for with habitat/resource replacement
  - Replacement ecological or human services provided through remediation actions
- Equivalency analysis enables calculation of the amount of habitat/resource to be created or enhanced to provide the same level of services over time as were damaged

Brief Overview of Equivalency Analysis

- Method designed in U.S. to provide compensation for damage
- Losses from damage are known as the "debit"
- Gains from remediation are known as the "credit"
- Referred to as "habitat equivalency analysis" (HEA) or "resource equivalency analysis" (REA)
  - Value equivalency analysis (VEA)
- Has been applied through U.S. for many types of incidents
  - International applications



Resource Equivalency – Required Information

- What has been damaged?
- How much damage has occurred?
- What is the duration of damage?
- What remediation projects can be implemented to offset damages?
- How successful will they be?
- How long will they take to provide benefits, and how long will benefits last?

The Language of Equivalency Analysis

- Services
  - The ecological or human functions of the damaged resource that serve as the basis of the equivalency analysis
- Debit
  - The amount of damage over time. Measured as "service loss."
- Interim loss
  - The total damage over time from the incident through completion of complementary/compensatory remediation
- Credit
  - The benefits provided by a remediation project. Measured as "service gain."
- Metric
  - The measure of services used to calculate both debits and credits
    - Vegetative cover, population density, biological diversity, etc.

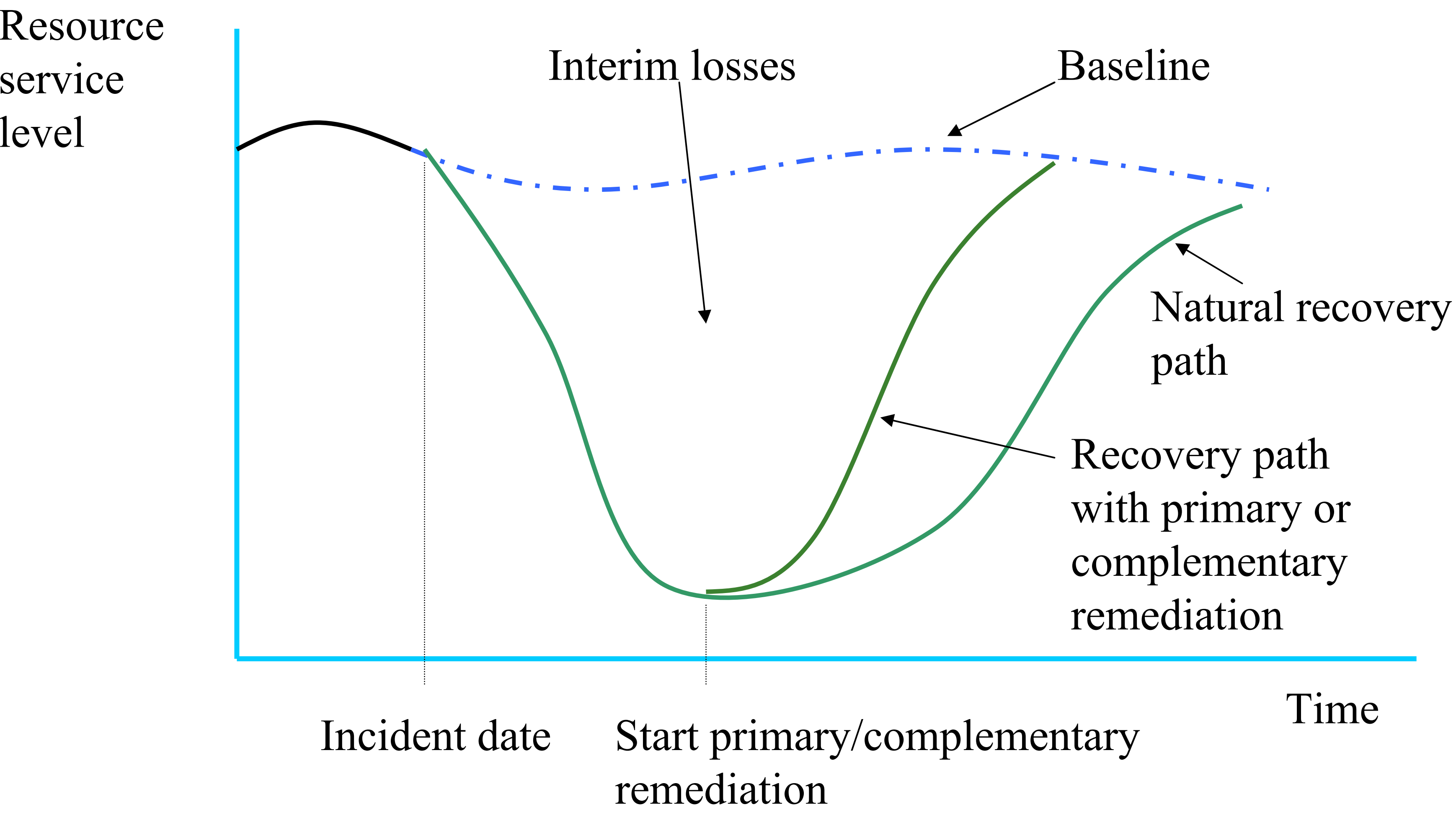
HEA, REA, VEA …

- Several variants of resource equivalency methods
- HEA: Habitat Equivalency Analysis
  - Units of environmental damage and remediation are expressed in terms of habitat
    - Hectares of damaged wetland
- REA: Resource Equivalency Analysis
  - Units of environmental damage and remediation expressed in terms of a specific resource
    - Number of brown trout
    - Bird productivity
- VEA: Value Equivalency Analysis
  - Units of environmental damage and remediation based on human preferences
    - Survey-based method

Remediation and Resource Equivalency Analysis under the ELD

- The ELD establishes 3 types of remediation
  - Primary remediation (on-site, to baseline)
  - Complementary (to fully remediate to baseline if primary remediation not sufficient)
  - Compensatory (to address interim losses)
- Equivalency methods designed to address complementary and compensatory remediation

Anatomy of Damages



Equivalency Analysis: Basic Steps

- Document and quantify the damage
  - What has been harmed?
  - How much damage? (“% service loss”)
    - Select a “metric” to describe the damage
  - For how long?
- Identify and evaluate remediation project options
  - How much ecological improvement from implementation of the remediation? (“% service gain”)
    - Based on the same metric as the damage
  - How fast will the resource recover?
  - For how long will benefits be provided?
- Scale the remediation project(s) to compensate for the damage

Basic Steps:(1) Document and Quantify the Damage

- Identify the types of habitats, biota, or resource services that have been damaged
- Identify one or more metrics
- Determine the extent of the damage, e.g.,
  - Area of injured habitat/resource; population reduction; biodiversity reduction, etc.
  - Severity of the injuries (e.g., 50% loss)
- Determine the duration of the damage
  - Is primary remediation being performed?
  - Will services return to baseline?
  - Recovery path/duration

Basic Steps (2):Identify and Evaluate Remediation Options

- What types of remediation projects could be conduct to replace, restore, or enhance services similar to those lost through damage?
- What credits will be generated by the remediation project(s)?
- How much time is required to implement the remediation project(s)?
- Following implementation, how long will the project(s) take to reach maximum function?

Basic Steps: (3) Scale Remediation to Compensate for the Damage

- Compute total discounted debit to reflect interim loss (in the past, present, and future) from the time of the incident
- Compute a total discounted credit to reflect benefits of the remediation
- Scale the remediation so that total discounted service losses of debit are equal to the discounted service gains of credit

Simple HEA Example – Wetland Damage

- A wetland is damaged, resulting in loss of habitat services
- Debit:
  - Hectares of damage x % Service Loss
  - Multiply by number of years of damage and incorporate discount rate to calculate present value of damage
- Credit:
  - What is the amount of compensatory remediation required to provide equivalent ecological services?

Wetland Example – the Debit

- What's the damage?
  - Ecological services provided by the wetland
    - Biodiversity, predator-prey relationships, habitat, protected species, etc.
- What's the metric?
  - Because everything is harmed in the simple example, we will use a "habitat-level" metric, as measured by percent vegetative cover of natural wetland species
- What are the level of services as measured by the metric?
  - Zero. No vegetative cover.
  - 100% service loss (relative to a baseline wetland in this area)

Wetland Example – the Debit

- What's the area of damage?
  - Assume 10 hectares
- Current level of debit?
  - 10 hectares x 100% service loss = 10 "service-hectares" of debit
  - If damage had been 50% service loss, then 10 hectares x 50% = 5 service-hectares of debit
- How long will the damage persist?
  - Assume 10 years from today (with instantaneous recovery!)
- Interim loss?
  - 10 service-hectares of debit x 10 years = 100 "service-hectare-years"
  - What about the present value of loss over this time?

Wetland Example – the Debit

- Discounted interim loss?
  - Converts to present value using a discount rate

Year	Discount Factor (@ 3%)	Damaged Ha	PV Damaged Ha
1	1.00	10	10.00
2	0.97	10	9.71
3	0.94	10	9.43
4	0.92	10	9.15
5	0.89	10	8.88
6	0.86	10	8.63
7	0.84	10	8.37
8	0.81	10	8.13
9	0.79	10	7.89
10	0.77	10	7.66
	Sum of PV Damaged Hectares (DSHaYs):		87.86

Wetland Example – the Credit

- Identify remediation alternatives
  - Assume wetland restoration
  - Similar habitat, similar ecological services, nearby location
  - Projects are feasible, desired by competent authority and public, and available

Wetland Example – the Credit

- Determine the DSHaYs of credit provided by each hectare of wetland creation
- How much service gain? How long to recovery? How long will services be provided?
  - Must use same metric!
  - Assume +50% service gain
  - Linear recovery over 10 yrs
  - Services continue 100 yrs

Wetland Example – the Credit

- Each hectare of remediated wetland generates 14.15 DSHaYs of credit

Year	Discount Factor (@ 3%)	Service gain (%)	PV Credit per Hectare
1	1.00	5	0.05
2	0.97	10	0.10
3	0.94	15	0.14
4	0.92	20	0.18
5	0.89	25	0.22
6	0.86	30	0.26
7	0.84	35	0.29
8	0.81	40	0.33
9	0.79	45	0.36
10	0.77	50	0.38
11	0.74	50	0.37
12	0.72	50	0.36
.	.	50	.
.	.	50	.
	Sum of PV Credit (DSHaYs) per hectare:		14.15

Wetland Example – Scaling Compensatory Remediation

- Total interim loss (debit) = 88 DSHaYs
- Total credit per each hectare of compensatory wetland remediation: 14 DSHaYs
- Compensatory remediation required =
  - 88/14 = 6.3 ha
- Why is required remediation (6.3 ha) < damaged wetland (10 ha)?

Wetland Example – Calculating the Liability

- Required compensatory remediation = 6.3 ha
- Calculate cost of remediation
  - Include costs of planning and design, permitting, implementation, oversight, operations/maintenance, monitoring, etc.
- Assume hypothetical unit cost of remediation = 100,000 Euros/hectare
- Total liability for hypothetical scenario =
  - 6.3 x 100,000 = 630,000 Euros

Case-Study Example: Resource Equivalency Analysis

Mining-damaged river.

- Damage caused by elevated concentrations of zinc and cadmium
- Contamination caused reductions to native trout population

Calculating the Debit

Sampling performed to determined the number of trout in affected areas relative to baseline conditions.

- Metric = trout population
- Upstream reference reach used to determine baseline
- Trout populations reduced from 12 trout/100m^2 to 2 trout/100m^2.
- Damages start in 1981 and continue for foreseeable future.

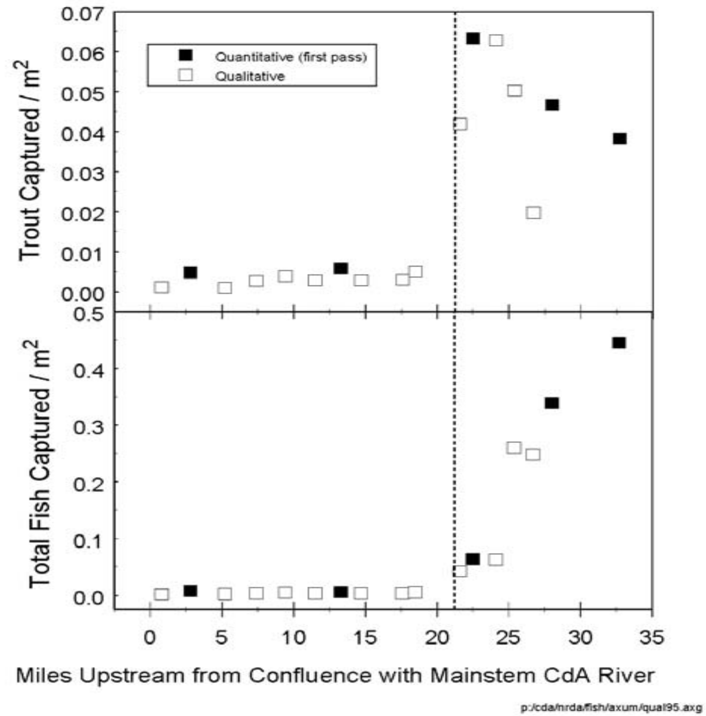
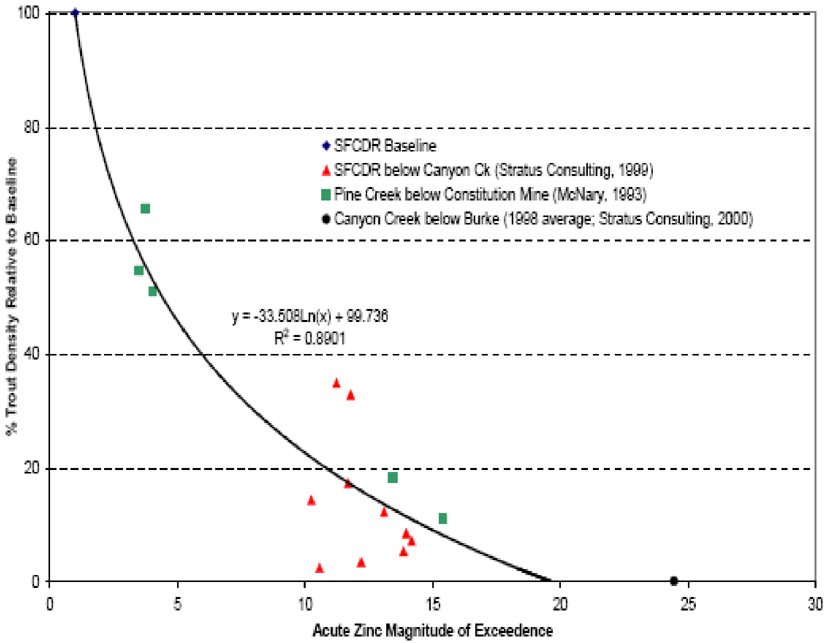


Figure 7-20. Trout (top panel) and all fish combined (bottom panel) collected in the South Fork Coeur d'Alene River during 1995 qualitative (open symbols) and first pass MPD (solid symbols).
Source: R2 Resource Consultants, 1996.

Calculating the Debit

- Benefits of primary remediation quantified based on relationship between zinc concentration and trout population



Remediation Alternatives

Road relocation/revegetation

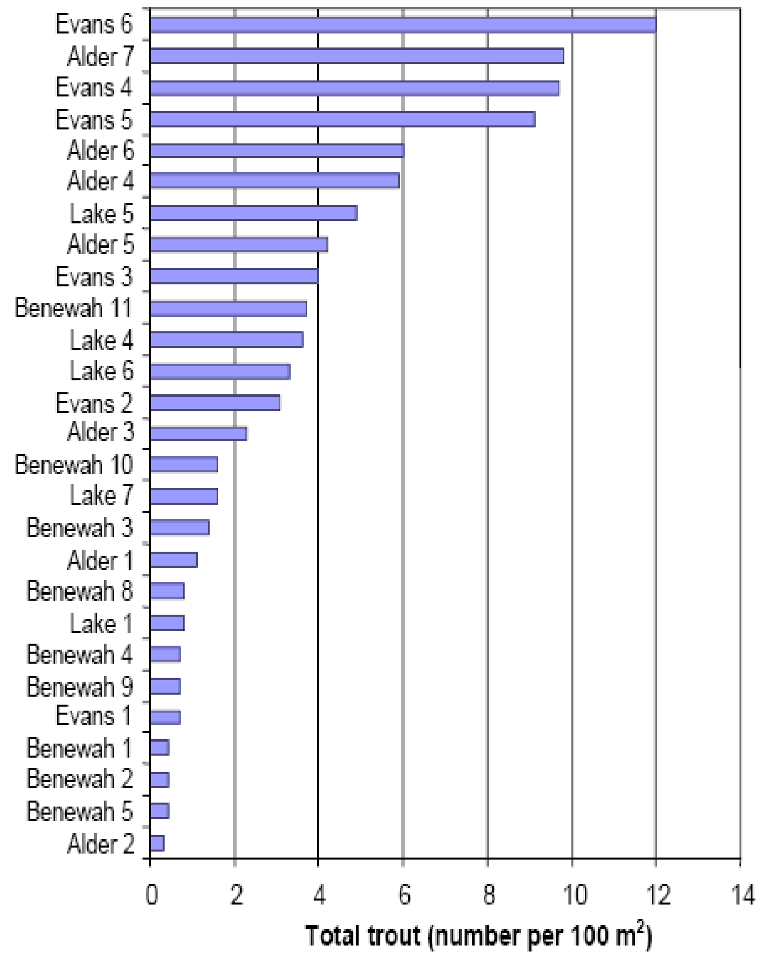
Woody debris

Channel Reconfiguration

Bank structures

Calculating Credits

- Published literature
- Local surveys regarding potential improvements in trout populations
  - %ile changes



Scaling Compensatory Remediation

Calculated total area of habitat improvement required to compensate for interim loss.

Table 4.17. Results of HEA calculations showing acres (and equivalent stream miles for the various enhancement project sizes) of habitat enhancement necessary to compensate for surface water injury. Results are provided for 5- and 10-year implementation scenarios. Stream miles are calculated for illustrative purposes based on average widths of the three size categories: small streams (6 feet), medium streams (15 feet), and large rivers (90 feet).

	Acres (miles) of surface water habitat replacement required	
Injured location	**5-year implementation**	**10-year implementation**
Canyon Creek	25.4 (34.9 miles of small stream) (14.0 miles of medium stream)	27.4 (37.7 miles of small stream) (15.1 miles of medium stream)
Ninemile Creek	23.3 (32.1 miles of small stream) (12.8 miles of medium stream)	25.2 (34.6 miles of small stream) (13.8 miles of medium stream)
South Fork Coeur d'Alene River	241.0 (22.1 miles of large river)	260.1 (23.8 miles of large river)

Calculating Total Liability

- Multiplied unit cost of remediation by total amount of remediation required.

Table 4.21. Total service replacement damages (millions of 2004 dollars) for Canyon Creek, Ninemile Creek, and the South Fork Coeur d'Alene River for 10- and 5-year implementation scenarios. The low estimate is calculated by summing lowest cost replacement project alternatives. The high estimate is calculated by summing the highest cost replacement project alternatives.

Implementation scenario	Low estimate	High estimate
10-year	$69.5	$192.0
5-year	$64.4	$177.9

Resource Equivalency - Summary

- HEA and REA are methods designed to quantify the amount of remediation needed to compensate for environmental damage
- Information needed to perform analyses:
  - What has been damaged?
  - How much damage has occurred?
  - What is the duration of damage?
  - What remediation projects can be implemented to offset damages?
  - How successful will they be?
  - How long will they take to provide benefits, and how long will benefits last?

REMEDE Toolkit

The Toolkit - Contents

PART 1: INTRODUCTION
INTRODUCTION TO RESOURCE EQUIVALENCY METHODS TO ASSESS AND SCALE ENVIRONMENTAL DAMAGE

PART 2: RESOURCE EQUIVALENCY
MAIN STEPS IN RESOURCE EQUIVALENCY METHODS TO ASSESS AND SCALE ENVIRONMENTAL DAMAGE

- **Step 1: Initial Evaluation**
- **Step 2: Quantify Debits**
- **Step 3: Quantify Credits**
- **Step 4: Scale Remediation**
- **Step 5: Monitoring & Reporting**

PART 3: ANNEXES TO THE TOOLKIT
BACKGROUND INFORMATION, DOCUMENTS AND REFERENCES

PART 4: PRACTICAL EXAMPLES
CASE STUDIES AND EXAMPLES

What isn’t in the toolkit?

- *Is the damage deemed ‘significant’?*
- *What and how much primary remediation should be undertaken?*
- *What should the baseline be?*

Step 1: Initial Evaluation

- Purpose: to determine whether an equivalency analysis should be performed

Key Questions to Answer in the Initial Evaluation:

Are natural resources likely to have been (to be) damaged by an incident covered by the ELD (or other framework)?

Are damages likely to be significant (to be determining by the Member States but likely including considerations about extent, severity and duration of damage)?

Will primary remediation fully compensate for environmental damage?

Would complementary or compensatory remediation be needed to offset losses?

Are services to humans likely to have been affected by the damage?

What is the appropriate level of detail of the assessment?

Initial Evaluation - Overview

- Description of the incident
  - What? Where? When? How much? Who?
  - Relevant legal framework(s)
- Preliminary identification of
  - available data
  - affected locations, environments, habitats, and species
  - extent of damages incurred or anticipated
  - potentially affected services
  - social, economic, transboundary issues
- Preliminary remediation planning
- Initiating and determining appropriate scale of assessment

Initial Evaluation

- Preliminary identification of potentially affected locations, environments, habitats, species
  - Facilitates identification of the resources most likely to have been affected or to be at risk from a given incident
- Preliminary identification of nature, degree, spatial and temporal extent of environmental damages incurred or anticipated
  - Have any resources been exposed to environmental stressors because of the incident?
  - What habitats/communities/species are likely to be at greatest risk?
  - Is there direct evidence of damage (e.g., fish kills)?
  - What is the nature of potential damages (e.g., mortality, habitat loss, population reductions, contamination that limits productive capacity of habitats, etc.)?
  - Is damage likely to be spatially widespread?
  - Is damage likely to continue into the future?

Initial Evaluation

- Preliminary identification of potentially affected services
  - Ecological services, e.g.,
    - Biodiversity
    - Habitat, shelter, prey
    - Nutrient flows
    - Assimilative capacity
  - Human services, e.g.,
    - Recreation
    - Option value
    - Existence value
    - Consumption
- Preliminary identification of social, economic, transboundary issues

Initial Evaluation

- Preliminary Remediation Planning
  - Will primary remediation be performed?
  - Will primary remediation restore baseline conditions rapidly?
  - Are complementary/compensatory remediation actions appropriate and feasible?

Complementary or compensatory remediation might be needed when:

Natural resources have been damaged or destroyed, or services provided by the resources have been (or will be) lost, as a result of an incident covered by the ELD or related directives.

Natural resources or the services provided by the damaged resource are not sufficiently replaced by primary remediation actions, or a significant damage or loss of services occurs because of the primary remediation.

Primary remediation is deemed unnecessary or impossible.

Primary remediation actions are not yet identified or cannot be conducted for some time, and complementary or compensatory actions should be implemented.

Significant damage will persist over a prolonged time period.

Incorporating Natural Resource Recovery Goals into Primary Remediation

Primary remediation is typically focused initially on eliminating or removing primary environmental stressors (for example, contaminant removals). Primary remediation can incorporate natural resource recovery goals. For example:

- Accelerate the recovery of a fully functioning ecosystem to baseline condition;
- Re-grade, re-contour, and re-vegetate with native species to accelerate natural recovery;
- Enhance aquatic habitat through riparian vegetation planting or in-stream work to restore ecological functions;
- Re-establish access to recreational services;
- Accelerate the recovery of resource uses, such as fishing, and
- Re-establish access to commercial services.

Initial Evaluation

- Should valuation approaches be considered?
  - Resources and services lost are not amenable to any type of remediation
  - Remediation will not be “in-kind” or “in-place”
  - Unique values were lost
  - Remediation costs disproportionate to value

Initial Evaluation

- Determine the scale of the assessment
  - Scale of the assessment can depend on the degree, severity, duration and extent of damages
  - the sensitivity or scarcity of affected resources and services
  - Other transboundary, cultural and political issues
- Expedited assessments
  - Existing data or models
- Extended and comprehensive
  - Additional data collection and analysis
  - Site-specific studies
  - Detailed modeling

Initial Evaluation - Conclusions

A resource equivalency equivalency analysis may be needed and warranted if:

- An incident covered by the ELD or related directives or frameworks has occurred or may occur;

- The quantity and concentration of contaminants released is sufficient to potentially cause harm to natural resources, or the degree of physical damage is sufficient to potentially cause harm to natural resources;

- Natural resources, or services provided by the natural resources, are potentially damaged;

- Primary remediation actions will not adequately remedy the harm resulting from the incident;

- Opportunities potentially exist offsite to conduct complementary and compensatory remediation projects

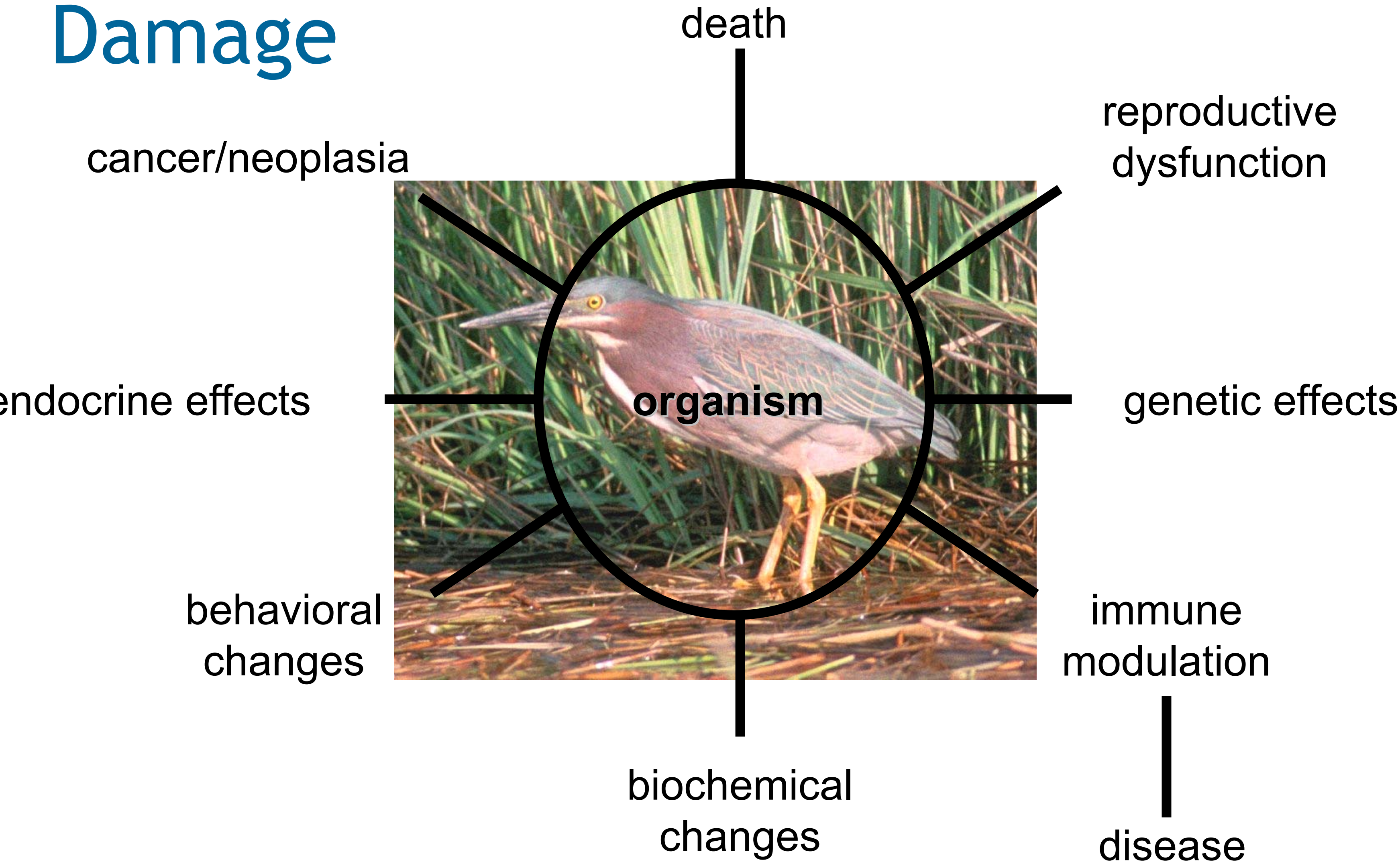
Step 2: Determining and Quantifying the Debit

- Identify damaged resources, habitats, and services
- Determine causes of damage
- Quantifying damages
- Calculating interim losses and total debits

Determining the Debit

- Identify damaged resources, habitats, services
  - Thorough evaluation of stressors associated with the incident
  - Conceptual model of system
  - Exposure evaluation
  - Receptor evaluation
  - Determination of the damage
- Damages can occur at level of individuals, populations, habitats, resources, e.g.,
  - Mortality
  - Loss of habitat functions
  - Reduced biodiversity
  - Impaired water quality,
  - Etc.

Examples of Potential Biological Damage



Damages to Populations, Habitats, Landscapes

- Population change
  - Abundance
  - Recruitment
  - Structure (age, siz etc.)
- Habitat
  - Diversity
  - Composition
  - Function
- Landscape
  - Diversity
  - Function
  - Cover
  - Interactions

Approaches to Determining Damage

- Existing data and literature
- Laboratory toxicity studies
- Field studies
- Models

Baseline Conditions

- Damages are quantified relative to baseline conditions
  - Conditions that would be expected to exist but for the incident in question
  - Baseline does not mean "pristine"
- Characterizing baseline?
  - Historical photographs and information
  - Before-after data
  - Use of control or reference areas
    - Should be chosen carefully to match impact area in all important ecological/land use features
    - "Before-after-control-assessment"
  - Models

Quantifying the Debit

Quantifying damages in equivalency analysis requires determining:

- The spatial extent of damage and service loss;
- The temporal extent (past, present, and expected future) of damage and service loss; and
- The degree of damage and service loss (often expressed in percentage of services provided relative to baseline conditions, or in numbers of organisms or a reduction in the quality of a characteristic of the organism – e.g., lifespan or fecundity).

Quantifying the Debit

- Select one or more metrics based on damage determinations
- Metrics can, conceptually, be selected at multiple levels of ecological organization
  - Community, habitat, population, individual
- Metrics can also include direct quantification of resource "units" (e.g., liters of water, kg of soil, etc.)
- Metrics should have the following "qualities"
  - Amenable to remediation
  - Applicable to both "debit" and "credit" side of analysis
  - Scalable (qualitative rankings may be acceptable) in terms of both "debit" and "credit"
  - Must demonstrate lexicographic preferences

Metrics (cont.)

- Metrics may be generalized or site-specific
- Metrics may be quantitative or qualitative (but must be scalable)
- Metrics may be single-attribute or multi-attribute
  - However, multi-attribute metrics must demonstrate lexicographic preference ordering (watch out for multi-variate biological "indices"!)

Metrics (cont.)

- Community-level metrics
  - Total biomass
    - E.g., vegetative biomass
  - Species composition (quantitative; single or multi-attribute)
    - E.g., number of taxa, diversity indices, macroinvertebrate community composition

Metrics (cont.)

- Habitat-level metrics
  - Percent vegetative cover
  - Biodiversity measures
  - Exceedence of habitat-level contamination concentration thresholds
  - Temperature amplitude

Metrics (cont.)

- Population-level metrics
  - Population density (e.g., fish per m^2)
  - Population biomass (trout kg)
  - Age-size distribution
  - Toxicity thresholds
- Individual-level metrics
  - Replacement of individual (protected) organisms
  - Frequency of tumors, other necrotic injuries
  - Individual organism-years

Some Common Metrics

- Area of devegetated terrestrial habitat (ha)
- Area of habitat (terrestrial, aquatic) in which contaminant concentrations exceed toxicological thresholds (ha, km of stream)
- Fish density (number per m^2)
- Fish biomass (kg)
- Bird production (bird years foregone)

Using Habitat "Scalars"

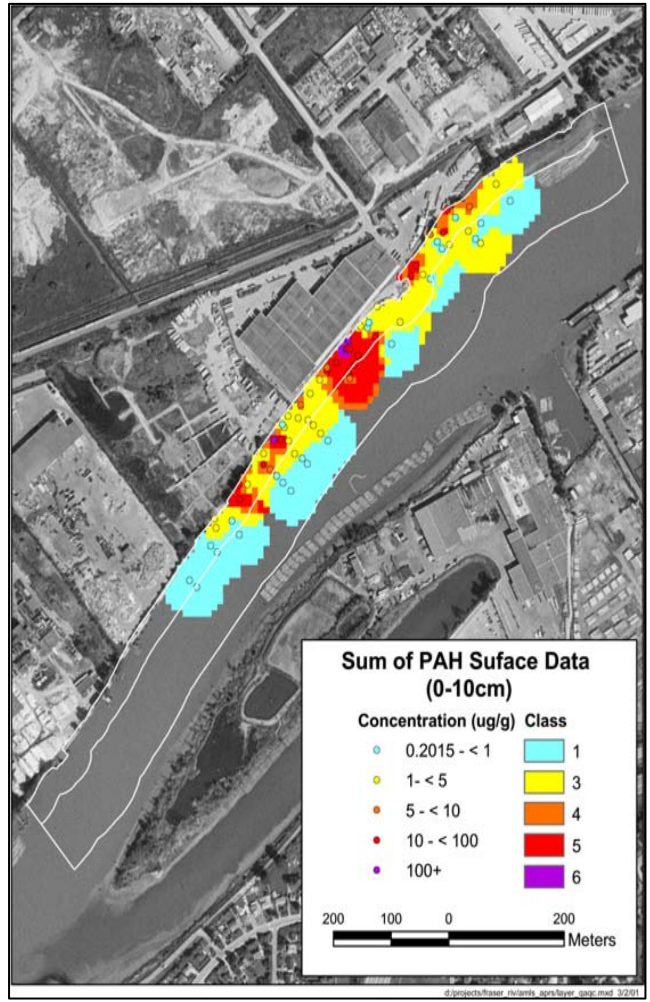
- In some cases, multiple habitats may be damaged, but remediation focuses on a "preferred" habitat type. E.g.,
  - Remediation alternatives may not be available for all habitats/species
  - Likelihood of success may be greater for certain habitats
  - Competent authority may want to focus on scarce habitats
- Habitat "scalars" are used to adjust between habitat types
  - Relative habitat productivity, diversity, etc.
  - Relative scarcity

Example of Habitat Scalar

- Three types of habitat damaged adjacent to a river:
  - Important, scarce, riparian wetland
  - Common mixed-shrub woodland
  - Common grassland
- Competent authority may wish to emphasize remediation of important, scarce wetland
- Habitat scalar used to “normalize” all habitat types into “preferred” habitat for remediation:
  - 1 ha wetland = 5 ha shrub/woodland = 15 ha grassland

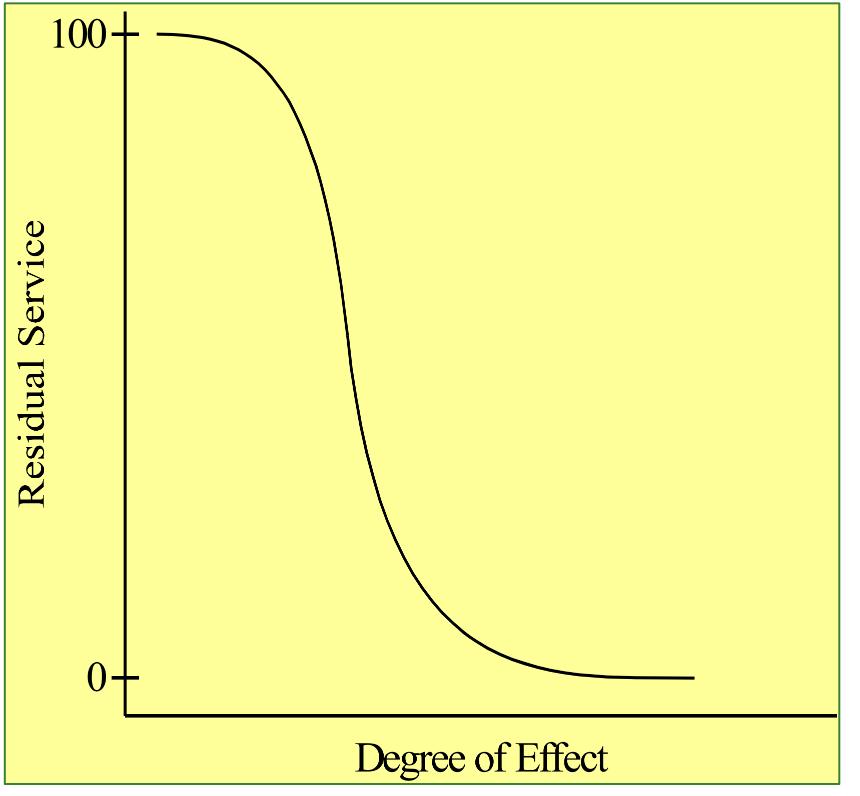
Contaminated Site: Illustration

- Sediment contamination with PAH from industrial operations

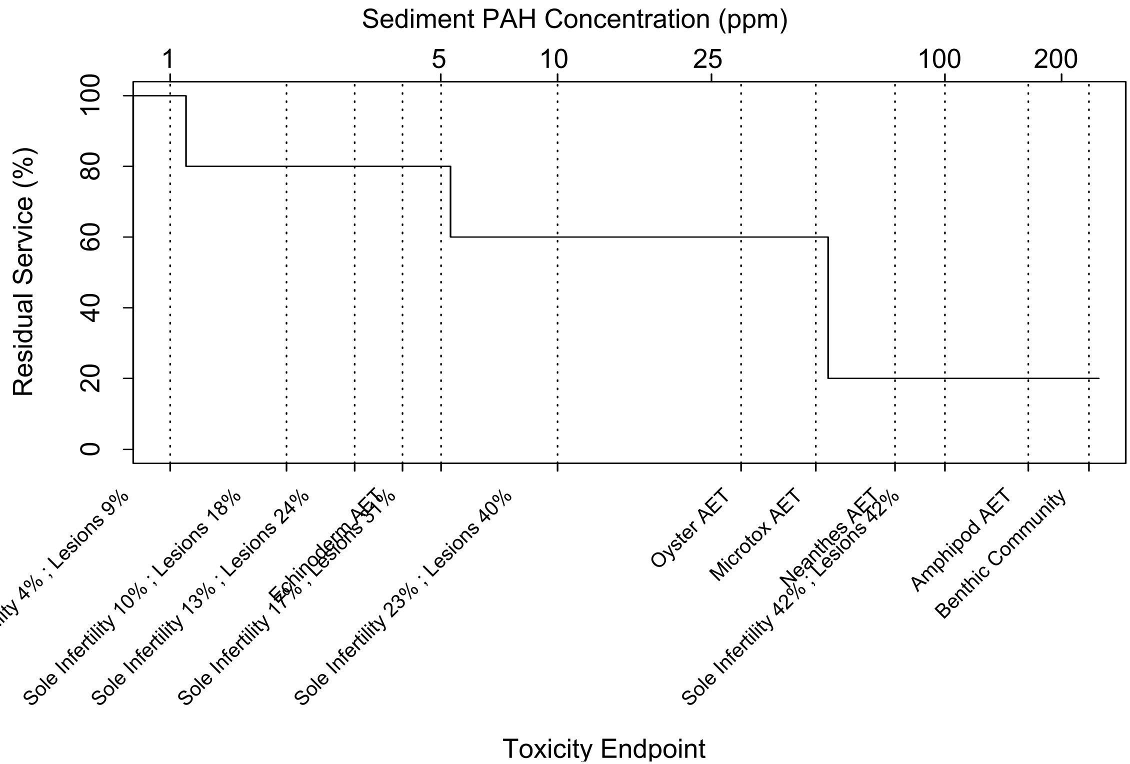


Contaminated Site - Service Loss

- Focus on loss of "sediment services" in affected habitats. Metric = healthy sediment.
- Conceptually, as degree of contamination and adverse effects increase,
  % services decrease.

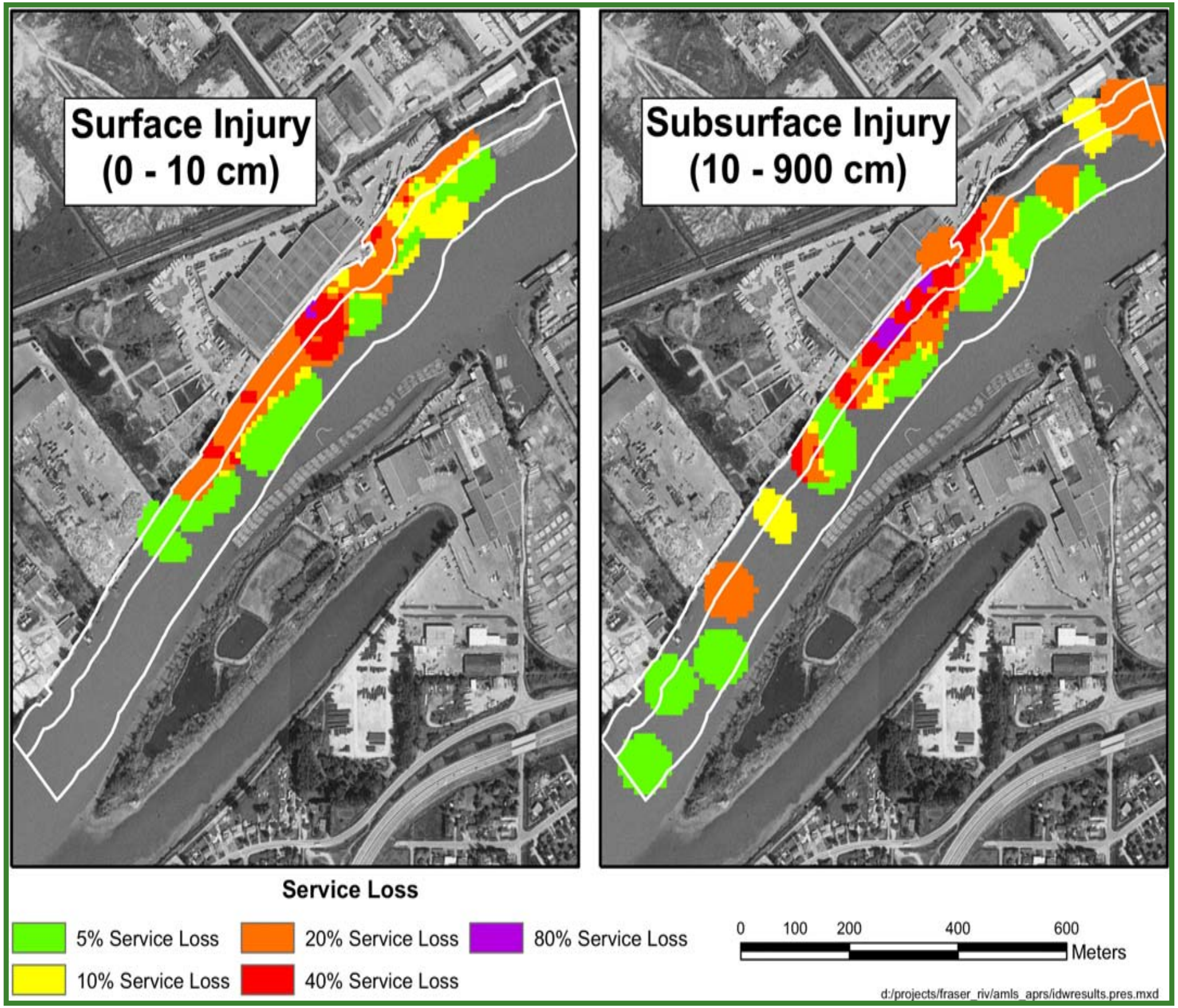


Sediment Toxicity Data used to Calculate Service Losses



By ordering effects thresholds, a toxicity-service loss "map" was generated (Cacela et al., 2005, *Environ. Manage.*)

Service Loss Assignment



Service losses assigned using toxicity data and information on spatial extent of contamination.

Contaminated Site – Habitat Scalars

- Habitat scalars used to adjust damages to nearshore surface sediments
  - Scalars reflected differences in relative ecological productivity
    - Nearshore/surface = 1.00
    - Offshore/surface = 0.50
    - Nearshore/subsurface = 0.10
    - Nearshore/subsurface = 0.05

Determination of Recovery Rates

- Must be estimated for both damaged and remediated environments (debit and credit)
- Recovery rates are conceptually site-specific but are almost always generalized
  - Published literature

Recovery Rates - Issues

- Recovery rates for <u>damaged environments</u>
  - Availability of published literature may be limited
  - Similarity of other analogue sites?
  - Recovery rates depend on the service metric selected! (Strange et al.)
    - E.g., 5 yrs for vegetative cover, 10 yrs for nutrient cycling, 15 years for finfish + invertebrates …
  - Use of "reasonable worst case scenario?" to represent precautionary principle

Calculate Interim Loss and Total Debits

Calculating interim loss and total debits: Key Steps

- Calculate total debits over time, accounting for benefits of any primary remediation
- Determine recovery rates
- Consider collateral damage
- Calculate the final debit on a present-value basis

Step 3: Determining and Quantifying the Gains from Remediation (the Credit)

- Identify and evaluate remediation alternatives
- Calculate service gains from remediation
  - Use same metric as for debit calculations

Examples of Common Types of Remediation Projects

- Habitat improvements or creation
  - Forests, wetlands, streams, ponds, etc.
- Resource improvements
  - Spawning, stocking, replanting, water treatment, etc.
- Contaminant cleanup
- Resource protection or preservation
  - Remember, benefits only from net improvement in resource condition

Criteria to Evaluate Remediation Projects

- Criteria provide objective basis for project selection
- Public transparency
- Provide means to articulate management goals (other than just "least cost")
- ELD (Annex II, 1.3.1) identifies 9 criteria, including collateral damage of projects, consideration of "relevant social, economic and cultural concerns", geographical linkage to the damaged site
  - *Note that Annex II, Section 2 states that remediation of land damage must eliminate risks to human health*
- Toolkit identifies additional criteria that may be considered

Evaluation Criteria - ELD

Box 1 Criteria for evaluating remediation options explicitly mentioned in the ELD

In its Annex II, the ELD explicitly mentions a number of criteria for evaluating reasonable remedial options using best available technologies. These are:

- Effect on public health and safety
- Cost of each option
- Likelihood of success of each option
- extent to which each option will prevent future damage, and avoid collateral damage as a result of implementing the option benefit to each component of resource/service
- Social, economic, cultural concerns and local factors
- Time needed for restoration of damage
- extent of restoration of the damaged site
- Geographical linkage to the damaged site

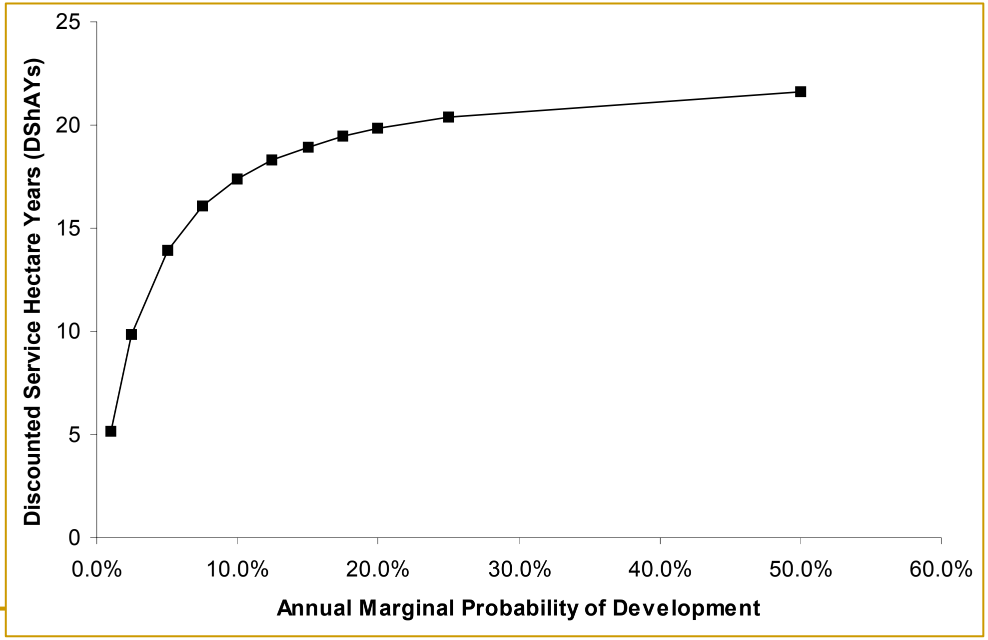
These criteria are given without attributing a specific priority or importance and without excluding the usage of other criteria that might be relevant for specific cases.

aluation of potential aquatic remediation projects

Evaluation Criterion	Remediation Project Type						
	Fish spawning habitat	Fish reintroduction	Angling management	Channel improvements	Navigation control	Vegetation buffers	Aquacultur
Initial Screening							
exus to damaged resources	+	+	+	+	+	+	+
Legal	+	+	+	+	+	+	+
No risks to public	+	+	+	+	+	+	+
Feasible	+	+	+	+	+	+	+
on't cause harm	+	+	+	+	+	+	+
ublic acceptance	+	+	?	+	?	+	+
Detailed Screening							
Address priority resources	+	+	+	+	+	+	?
Use reliable methods	+	+	+	+	+	+	+
Costs<benefits	+	+	+	+	?	+	?
Readily scaled to debits	Low	Low	Low	High	Low	Low	Low
Benefits can be quantified	High	Low	Low	High	Low	High	High
Consistent with egional planning	High	High	Low	High	Low	High	High
Provides benefits to multiple resources	High	Low	High	High	High	High	Low
Enhance public enjoyment	High	High	Low	High	Low	High	High
rovide long-term benefits	High	High	?	High	?	High	Low
Provides benefits o comprehensive segment of population	High	High	Low	High	Low	High	Low

Evaluating Remediation Projects

- Potential for inappropriate preference for replacement over primary remediation because of cost differences
- Double-counting projects that would otherwise have been implemented
- Geographic/social/political issues
- Risk of failure
- Overvaluing protection



Recovery Rates – Remediated Environments

- Limited published record
- HEA/REA often assume stable recovery endpoints – this may not be correct
- Recovery rates depend on service metric
- Remediation typically uncertain. Some likelihood of failure should be recognized.
- Remediated environment may not provide full services
- Remediation, itself, may cause temporary service loss. This should be incorporated into the "debit."

Evaluating Service Gains

Calculating service gains (credits) of remediation options

Quantifying the benefits of potential remediation projects (credits) requires developing a similar set of information as for quantifying damage (debits). The anticipated timing and degree of productivity of the remediation actions must be evaluated in terms of the chosen metric, and the anticipated productivity should be compared to the total amount of services that would have been provided by the damaged site had the damage not occurred.

Step 4: Scaling Remediation

- Calculate the amount of required remediation
- Calculate the costs of implementing the remediation alternative(s)

Calculating Required Remediation - Debit

Example of debit calculations. This example assumes 1 hectare of land with a 50% service loss during 2004-2009.			
Year	**Percent service loss**	**Present value factor[a]**	**Debit[b] (DSHYs)**
2004	50%	1.09	0.55
2005	50%	1.06	0.53
2006	50%	1.03	0.52
2007 (base year)	50%	1.00	0.50
2008	50%	0.97	0.49
2009	50%	0.94	0.47
Total			**3.05**

1. a. Present value factor = $1 / (1+ \text{discount rate})^{(\text{year} - \text{base year})}$.
   b. Debit is calculated by multiplying percent service loss by present value factor.
2. Note: the discount rate = 3% and the present value year = 2007.

Calculating Required Remediation - Credit

Example of credit calculations. This example assumes 1 hectare of land with a service gain increasing to 50% over baseline service levels from 2009 to 2013.			
Year	**Percent service gain**	**Present value factor[a]**	**Credit[b] (DSHYs)**
2009	10%	0.94	0.094
2010	20%	0.92	0.183
2011	30%	0.89	0.267
2012	40%	0.86	0.345
2013	50%	0.84	0.419
Total			**1.31**

1. a. Present value factor = 1 / (1+ discount rate)$^{(\text{year} - \text{base year})}$.
   b. Credit is calculated by multiplying percent service gain by present value factor.
2. Note: the discount rate = 3% and the present value year = 2007.

Debit = 3.05 DSHaYs. Credit = 1.31 DSHaYs per remediated hectare. Required remediation = 3.05/1.31 = 2.3 hectares.

Calculating Remediation Costs – Cost Components

Summary of important cost components when estimating remediation cost	
Cost	**Description**
Planning	Planning and design, including preliminary surveys.
Acquisition of permits, land	Acquisition of any necessary permits or access requirements. Land (or other assets) may need to be acquired.
Implementation	Labour, materials, transport, infrastructure development, site management and oversight, supplies.
Operation and Maintenance	All costs required to run and manage the project, including labour, equipment, materials, and supplies.
Oversight	Oversight by Competent Authorities, including labour time and administrative overhead costs.
Monitoring and Reporting	Including costs of labour, materials, supplies, and information dissemination.
Failure contingency	All necessary and appropriate contingency costs that apply to uncertainties associated with project execution. General practice is between 20-40% of total estimated costs.

Step 5: Monitoring and Reporting

- Remediation planning and implementation
- Monitoring remediation success
- Reporting

Monitoring

- Essential element of remediation process
- Toolkit provides detailed recommendations

Framework for Post-Remediation Monitoring

Post-remediation monitoring is a key step in the remediation process. An effective post-remediation monitoring plan will help to

- identify problems that could be corrected;
- quantify benefits; and
- provide information that can be communicated to policy-makers and the public about the benefits of remediation.

Before developing a post-remediation monitoring plan, the conceptual model for a project must be specified. This model should clearly delineate the remediation action, the expected intermediate outcome, and the pathway/process by which the intermediate outcome will lead to the desired long-term results.

An effective monitoring framework takes advantage of the conceptual model to provide important information for each step of the remediation process. Ideally, the monitoring framework will include both pre-implementation monitoring to determine initial conditions and references sites that will be monitored simultaneously with the project site. Because baseline conditions can change over time (for example, a drought may cause a regional decrease in fish populations), monitoring changes in reference conditions over time allows for appropriate adjustments to be made to baseline conditions.

For each step in the monitoring framework, a plan should be developed that specifies:

- who will be responsible for monitoring;
- to whom results will be reported;
- the objective of that monitoring step;
- the monitoring actions to be taken;
- the location of the monitoring;
- the timing of the monitoring; and
- any benchmarks that will trigger corrective action.

Overview of Monitoring Steps

Step 1: Monitor project sites and appropriate reference sites to establish pre-implementation conditions

Step 2: Monitor implemented action to determine if the implementation has been successful. These results should trigger corrective actions to implementation if necessary.

Step 3: Monitor project site and reference sites over short-term (often 1 – 5 years) to determine if the implementation has achieved the intended intermediate outcomes. These results should trigger corrective actions if necessary.

Step 4: Monitor project results and reference sites over the long-term (often 3 – 10+ years) to quantify project outcomes compared to baseline conditions. Baseline conditions should be adjusted for temporal changes based on similar changes at reference sites.

Monitoring Plan - Illustration

Monitoring Approach: Fish Passage Structure at a Dam

	Pre-implementation and reference site data collection. *Goal of monitoring: Establish baseline conditions*	**Implemented Action(s)** *Goal of monitoring: Has the implementation been successful?*	**Intermediate Outcome** *Goal of monitoring: Has the implementation achieved the intended result?*	**Process** *(How is final endpoint achieved?)*	**Long-term Results:** *Goal of monitoring: Has the intermediate outcome achieved the desired long-term result?*
OBJECTIVE OF ACTION	Establish baseline fish population data above barrier and in similar reference reaches	Passage installation	Provide brown trout access to high-quality habitat above the dam	Access to more refugia, overwintering, and spawning habitat will increase brown trout population	Increase in brown trout population (density, biomass, and age-class distribution)
MONITORING ACTION DESCRIPTION	Fish surveys using electrofishing	Check that integrity of passage structure is intact and that structure provides passage in all flow conditions	Fish surveys using electrofishing and visual observations of passage structure integrity to confirm that structure provides fish passage		Fish surveys (electrofishing) to determine density, biomass, and age structure of brown trout above barrier
TIMING OF ACTION	Fall surveys before implementation at project site; fall surveys at reference sites concurrent with post-remediation monitoring	Monitoring during low, medium, and peak flow conditions for first year	Periodic visual observations by staff in area; Annual fall fish surveys via electrofishing for 3 years		Fall fish surveys in Year 5, 10, and 15
LOCATION OF ACTION	Sites above the dam for 2 km until habitat changes; Sites in reference reaches with similar habitat	At the barrier	Sites above the dam for 2 km until habitat changes; Sites in reference reaches with similar habitat		Sites above the dam for 2 km until habitat changes; Sites in reference reaches with similar habitat
BENCHMARK	No benchmark	Structure is intact; fish passage noted in all flow conditions	Brown trout population above dam exceeds baseline population		Brown trout population above dam is 50% higher than baseline population (adjusted for annual fluctuations using reference site data)

Reporting

- Reporting not an ELD requirement of the ELD. However, Authorities may wish to consider making damage assessment reports available for public review at regular intervals and in an accessible format.

Reporting: Purposes

- Communicating remediation plan successes (and failures) to the affected publics
- Communicating necessary alterations in monitoring design or anticipated recovery rates to the affected public
- Communicating any potential human health risks (or lack thereof) to the affected public
- Contributing to scientific knowledge regarding remediation efficacy and recovery rates

Practical Implications of This Kind of Analysis?

Then…

…and Now